



Impacts of COVID-19 and Exchange Rates on Olive Oil Markets and Food Security

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Abstract

The objective of this research is to identify the long-term fluctuation spillovers in the Turkish extra-virgin olive oil and crude olive oil markets using COVID-19 and the external dollar exchange rate variables and to examine the asymmetry of these spillovers. The analyses required for this research were performed with the VECM (1)-Asymmetric BEKK-GARCH (1, 1) model, using daily data for the period from May 2005 to June 2024. According to the empirical findings, both brief shocks and long-term uncertainties have significantly increased the conditional variances of the extra-virgin and crude olive oil return series. An increase in long-term uncertainty in the extra-virgin olive oil market has a dampening effect on the long-term volatility in the crude olive oil market. It was observed that the conditional variances of the extra-virgin and crude olive oil return series were negatively affected by fluctuations stemming from COVID-19 in the long run. In the long term, COVID-19 increased uncertainties in bilateral interactions between markets, seriously threatening food security by negatively impacting consumer access to crude and extra-virgin olive oil. It was noted that fluctuations in the exchange rate reduced the volatilities in the extra virgin and crude olive oil markets. It is recommended that policymakers in Türkiye implement specific policies for food commodities, considering the possibility of disruptions in global food supply chains due to pandemics or similar crises.

Keywords: COVID-19, Exchange Rates, Olive Oil Markets, Prices, Volatility, Food Security

Jel Codes: D40, C22, Q18

COVID-19 ve Döviz Kurunun Zeytinyağı Piyasaları ve Gıda Güvenliği Üzerindeki Etkileri

Öz

Bu araştırmanın amacı, COVID-19 ve dışsal dolar döviz kuru değişkenleri kullanılarak Türkiye’de sızma zeytinyağı ile ham zeytinyağı piyasalarındaki uzun vadeli dalgalanma yayılımının belirlenmesi ve bu geçişkenliklerin asimetrikliğini araştırmaktır. Bu araştırma için gerekli analizler, Mayıs 2005 ile Haziran 2024 arasındaki döneme ait günlük veriler kullanılarak VECM (1)-Asimetrik BEKK-GARCH (1, 1) modeli ile gerçekleştirilmiştir. Ampirik bulgulara göre, hem kısa vadeli şoklar hem de uzun dönemli belirsizlikler sızma ve ham zeytinyağı getiri serilerinin koşullu varyanslarını önemli düzeyde artırmıştır. Sızma zeytinyağı piyasasındaki uzun vadeli belirsizliğin artışı, ham zeytinyağı piyasasındaki uzun dönemli volatilitiyi azaltıcı bir etki yapmaktadır. Sızma ve ham zeytinyağı getiri serilerinin şartlı varyanslarının uzun vadede COVID-19’dan kaynaklanan dalgalanmalardan negatif yönde etkilendikleri görülmüştür. Uzun vadede COVID-19, piyasalar arası ikili etkileşimlerdeki belirsizlikleri artırmış ve tüketicilerin ham ve sızma zeytinyağına erişimini olumsuz etkileyerek gıda güvenliğini ciddi şekilde tehdit etmiştir. Döviz kurundaki dalgalanmaların sızma ve ham zeytinyağı piyasalarındaki oynaklıkları azalttığı gözlenmiştir. Türkiye’deki politika yapıcılara, pandemi veya benzeri krizler nedeniyle küresel gıda tedarik zincirlerinin bozulma olasılığı dikkate alınarak gıda ürünlerine yönelik spesifik politikaların uygulanması önerilmektedir.

Anahtar Kelimeler: COVID-19, Döviz Kuru, Zeytinyağı Piyasaları, Fiyatlar, Oynaklık, Gıda Güvenliği

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INTRODUCTION

Olive oil not only holds economic significance for producers but also stands as a crucial nutritional element for consumers, thus bearing immense importance both economically and nutritionally (Gontijo, 2020). Positive effects from olive oil on health, paralleling the increasing importance of the Mediterranean diet, have led to a substantial rise in global consumption (Gázquez-Abad & Sánchez-Pérez, 2009; Salas-Salvadó et al., 2018). On the demand side, as the allure of the product extends beyond the Mediterranean, world olive oil consumption has witnessed a noteworthy increase over the last thirty years, growing by 1.8 times in volume between 1995–1996 and 2019–2020 (Mili & Bouhaddane, 2021). Moreover, significant growth in olive oil demand is anticipated in unconventional marketplaces globally. This is fuelled by increasing awareness of the product's favorable qualities for sustainability and health, as well as shifts in consumer lifestyles and rising incomes (Gorzynik-Debicka et al., 2018).

Research in medicine has shown the significant associations of consistent use of olive oil with low cholesterol and blood pressure (Storniolo et al., 2017), reduced risk of specific types of cancer (Reboredo-Rodríguez et al., 2018), prevention of cardiovascular diseases (Salas-Salvadó et al., 2018), and assistance in the absorption of calcium (Clodoveo et al., 2014; Xiong et al., 2014). Approximately 70% of olive oil production originates from the Mediterranean, with a substantial portion supplied by European Union countries, particularly Italy, Greece, and Portugal, representing nearly 43% of total production. Following them are countries in the Southern Mediterranean like Türkiye, Morocco, Algeria, Tunisia, and Syria, contributing to 24% of the output (Romo Munoz et al., 2015). Data indicate that despite significant fluctuations in production among other producer countries, Türkiye remains an important player in the global market for olive oil (Mili & Bouhaddane, 2021).

The olive oil market in Türkiye is a significant component of the global olive oil industry, characterized by its unique production methods, diverse cultivars, and regional economic importance. Türkiye ranks as the fifth largest producer of olive oil globally, contributing approximately 5% to the world's production and 11.3% to its exports (Gökçebağ et al., 2013; İlyasoğlu et al., 2010). The Aegean region is the primary hub for olive oil production in Türkiye, accounting for about 75–80% of the total output, with the Ayvalık and Memecik cultivars being the most commercially significant (İlyasoğlu et al., 2010; Dağ et al., 2015).

In terms of market dynamics, the Turkish olive oil sector faces both challenges and opportunities. Competition from other Mediterranean countries, particularly Spain and Italy, poses a significant challenge, as these countries have established strong brand identities and consumer loyalty in international markets (Arfaoui et al., 2022). However, the increasing global demand for high-quality olive oil, particularly extra virgin olive oil (EVOO), presents an opportunity for Türkiye to enhance its market share (Azak & Tuzun, 2012; Ruiz-Carrasco, 2023).

Producer prices fluctuate based on supply and demand, influenced by speculative movements in the market, currency fluctuations (more imports and fewer exports are typically associated with a stronger currency, thereby decreasing home production's ability to compete internationally), policies, information asymmetry, and global pandemics such as COVID-19 (Mili & Bouhaddane, 2021). Research on olive oil production and consumption suggests that this process involves dynamics that can similarly impact producers and/or consumers concerning price changes (Vlontzos & Duquenne, 2014;

Bajoub et al., 2016). In this context, the analysis of olive oil price volatility holds vital importance. This significance arises not only from olive oil being a high-value food source but also from the potential of production inconsistencies to cause price differentials. Cyclical variations in the seasons can significantly affect the earnings of farmers while disrupting consumption levels for urban populations. Consequently, being aware of the fluctuation patterns of these prices can assist in designing policies to keep the price of products stable over time.

From the 2011-2012 crop year to the harvest year 2022-2023, the pricing dynamics of extra-virgin olive oil in various key regions provide revealing insight into the market trends. In Jaén, Spain, the cost of extra-virgin olive oil was below €227.5 per 100 kg for 25% of the time during this period, while 25% of the time, it surpassed €336.8 for every 100 kg. The mean price stood at approximately €291.5 for every 100 kg, with the highest and lowest prices recorded at €536 and €174.3 for every 100 kg, in that order. Recent data from the International Olive Council (IOC) indicates a current price of €519 per 100 kg, reflecting a notable increase of 43.2% in comparison with the same time frame in the prior crop year. Prices of refined olive oil in Jaén, Spain, also experienced a significant rise, reaching €485 per 100 kg, marking a 43.1% increase from the previous crop year. In Bari, Italy, the pricing trends for extra-virgin olive oil saw it priced below €334 for every 100 kg for 25% of the time, while 25% of the time it surpassed €533 for every 100 kg. The mean price for this time frame was approximately €428 for every 100 kg, with the minimum and maximum prices reported at €614 and €221 for every 100 kg, in that order. The most recent IOC statistics reveal a current price of €603 per 100 kg, indicating a substantial increase of 40.9% in contrast to the same time frame in the prior crop year. Moving to Chania, Greece, the cost of extra-virgin olive oil was below €241 for every 100 kg for 25% of the time, and 25% of the time it surpassed €312 for every 100 kg. During this time, the average price was about €279.9 for every 100 kg, with the minimum and maximum prices reaching €475 and €182 for every 100 kg, in that order. According to the latest IOC statistics, the current price stands at €465 for every 100 kg, marking a significant uptick of 45.3% in contrast to the same time frame in the prior crop year. In Trás-os-montes, Portugal, the latest figures report a price of €600 for every 100 kg for extra-virgin olive oil. Meanwhile, the pricing trajectory for extra-virgin olive oil from Tunisia witnessed a decline starting in the 2019-2020 crop year, with a price of €192 for every 100 kg in September 2020. The mean for the crop year was €228.7 for every 100 kg, increasing to €328.1 for the 2020-2021 crop year. By March 2023, the price had further risen to €518 for every 100 kg. Lastly, the most recent Türkiye's extra-virgin olive oil statistics indicate a price of €264 for every 100 kg in December 2018 (International Olive Council, 2023).

The aim of this study is to identify the long-term fluctuation spillovers in the Turkish extra-virgin olive oil and crude olive oil markets using COVID-19 and the external dollar exchange rate variables, and to examine the asymmetry of these spillovers. The research employs the VECM (1)-Asymmetric BEKK-GARCH (1, 1) model, using daily data from May 2005 to June 2024. In this study, we examined to reveal what kind of return and uncertainty spillovers exist between crude olive oil and extra-virgin olive oil markets in Türkiye, in the context of the dollar exchange rate series and COVID-19. The macroeconomic variables of COVID-19 and the dollar exchange rate were examined. The analysis involved using daily data from May 2005 to June 2024 to determine the volatilities between the relevant markets. WinRATS-10 software was used for the analyses.

1. CONCEPTUAL FRAMEWORK

The conceptual framework of this study is built on the premise that the price movements of olive oil, both crude and extra-virgin, are influenced by a combination of factors, including the COVID-19 pandemic and exchange rate fluctuations. As mentioned earlier, olive oil production and consumption involve dynamics that can impact prices, leading to volatility. The COVID-19 pandemic, which began in late 2019, has had a far-reaching impact on global economies, affecting supply chains, consumer demand, and trade patterns. The pandemic's effect on oil prices, in general, has been predominantly negative, with prices declining significantly in the first quarter of 2020 due to reduced demand (Luo et al., 2023; Ghadir et al., 2022). However, the impact on the olive oil market may differ, as it is a specialized agricultural product with its own unique supply and demand characteristics. On the other hand, exchange rate movements can also significantly influence the pricing of olive oil, particularly in countries where the domestic currency differs from the US dollar, which is the global currency for commodities trading. These exchange rate fluctuations can affect the competitiveness of domestic producers, as well as the affordability of olive oil for consumers, potentially leading to changes in consumption patterns. Olive oil's dual role as an economic commodity and a nutritional staple highlights its importance, with growing global demand for extra-virgin olive oil underscoring its significance. The framework explores market volatility and spillover effects, using the VECM-Asymmetric BEKK-GARCH model to analyze dynamic interactions between extra-virgin and crude olive oil markets under external pressures. COVID-19's disruptions heightened uncertainty in global food supply chains, negatively affecting price stability and consumer access to olive oil, while fluctuations in the Turkish lira against the dollar further influenced production costs and market behavior. These market dynamics are linked to broader food security concerns, demonstrating how increased uncertainties can threaten access to essential commodities. The study emphasizes the importance of policy interventions in mitigating these risks. Leveraging nearly two decades of daily data, the framework employs robust econometric tools to assess short-term shocks and long-term uncertainties, providing a comprehensive basis for understanding market resilience and guiding effective policy measures.

2. MATERIAL AND METHODS

2.1. Material

The data used in the study for the extra-virgin and crude olive oil price series spanning May 2005 to June 2024 were obtained from the everyday records of the Aydın and Edremit Database for Commodity Exchange Markets. The series of real dollar exchange rates was acquired from the Electronic Data Delivery System (EVDS) of the Central Bank of the Turkish Republic (CBRT). The series of extra-virgin and crude olive oil prices used in the study is based on the index of food prices. The study investigated the COVID-19's effects variable on the relevant markets during COVID-19 compared to those without COVID-19. In addition to the price series, daily exchange rates, and dummy variables representing the impact of COVID-19 were constructed. All monetary value series were deflated. Upon conducting preliminary analyses, the connection between the yields and conditional variances of crude and extra-virgin olive oil was explored using the VECM (2)-BEKK-GARCH (1,1) model. Exchange rate return series and COVID-19 were included as additional variables in the return equations, while the exchange rate return squared variable and COVID-19 dummy variables were incorporated into the conditional variance model. The ARCH effect was identified in both individual and composite analyses of the return series for crude olive oil and extra-virgin olive oil, indicating that increasing returns triggered subsequent increases

and decreasing returns triggered subsequent decreases, affirming the suitability of the two-variable generalized GARCH model. Through AIC and BIC preliminary analyses, the lag length was determined to be four.

2.2. Econometric Method

This research examines the connection between extra-virgin olive oil and crude olive oil in the context of the uncertainties posed by COVID-19. To determine the impact of price uncertainty on these key food production commodities, the BEKK (Baba, Engle, Kraft & Kroner) Multivariate-GARCH model (Engle & Kronner, 1995) was used for the variance equation. The Vector Error Correction Model (VECM) was employed for the mean equation due to long-term cointegration, as identified by the Johansen (1995) cointegration test. In order to take into consideration how differently negative and positive shocks affect conditional variance, asymmetric effects were incorporated into variance equation (Rahman & Serletis, 2012; Salisu & Oloko, 2015). Conditional variances' square roots were included in the average measurement formulae their direct effect on commodity prices, after Rahman and Serletis (2012) and Grier, Henry, Olekalns and Shields (2004). Equations (1) and (2), in that order, show the average conditional and variance formulae used in this research.

$$\Delta P_{i,t} = \mu_i + \phi_i z_{t-1} + \sum_{j=1}^p \Gamma_{i,j} \Delta P_{i,t-j} + \psi E + \omega CV + \Psi_i \sqrt{h_{i,t-1}} + \varepsilon_{i,t-1}, \quad i = evo, coo \text{ and } j=1, \dots, p$$

$$\begin{pmatrix} \Delta P_t^{evo} \\ \Delta P_t^{coo} \end{pmatrix} = \begin{pmatrix} u_{evo} \\ u_{coo} \end{pmatrix} + \begin{pmatrix} a_{evo} \\ a_{coo} \end{pmatrix} z_{t-1} + \sum_{j=1}^p \begin{pmatrix} \Gamma_{evo,evo,j} & \Gamma_{evo,coo,j} \\ \Gamma_{coo,evo,j} & \Gamma_{coo,coo,j} \end{pmatrix} \begin{pmatrix} \Delta P_{t-1}^{evo} \\ \Delta P_{t-1}^{coo} \end{pmatrix}$$

$$\varepsilon_t \sim (0, H_t) \quad \text{and} \quad \varepsilon_{i,t-1} = H_{i,t-1}^{1/2} \eta_{i,t-1}, \quad (1)$$

In the formula (1), which serves as the equation for the conditional mean, the natural logarithm of extra-virgin olive oil and crude olive oil prices are represented by evo and coo, respectively. The real exchange rate that is added exogenously to the mean equations is denoted by 'E', while 'CV' represents the dummy variable used to assess the impact of COVID-19, being 0 for dates prior to December 1, 2020, and 1 otherwise. The first difference operator is represented by the symbol, while j denotes the lag parameter. The suitable lag length of was determined using the Bayesian Information Criterion in the study. The symbol represents the coefficient that reflects the impact of conditional variance on commodity prices.

The conditional variance used in this study to determine the uncertainty pass-through across commodities is illustrated in Equation (2).

$$H_t = \Upsilon \Upsilon' + A' \varepsilon_{t-1} \varepsilon_{t-1}' A + B' H_{t-1} B + D' \xi_{t-1} \xi_{t-1}' D \quad (2)$$

In the formula (2), H represents a 2x2 matrix that captures the conditional variance with a temporal dependence and covariance across different commodities. A, B, and D are 2x2 matrices that show the have an impact of brief shocks, long-term uncertainty, and asymmetry effects on the conditional covariance-variance, respectively. C is a constant term that accounts for the impacts of COVID-19 and dollar exchange rate on the conditional variance-covariance. The matrix is then transformed into a 2x2 upper triangular matrix, with E and CV appearing as such. Due to the nonlinear nature of the

equation, marginal effects must be estimated using the delta method. The VECM (2)-BEKK GARCH-M (1, 1) model is then calculated via the technique of quasi-maximum likelihood, assuming a conditional joint log-likelihood function of Gaussian and normal distribution of the observations t and two variables. The parameters are obtained by utilizing the BFGS algorithm. The log-likelihood function is mathematically represented as a normal distribution that follows a particular form.

$$\log - L = -0.5x \sum_{t=1}^T \left[k \log(2\pi) + \ln |H_{i,t}| + \varepsilon'_{i,t} H_{i,t}^{-1} \varepsilon_{i,t} \right] \quad (3)$$

Furthermore, the parameters derived from the formulae for mean and variance were subjected to testing for Granger causality, as well as the existence of GARCH, asymmetric, and diagonal GARCH effects using the Wald test. As demonstrated in Equation (2), the impact of the COVID-19 and dollar exchange rate on the conditional variance was assessed against the null hypothesis of “dollar exchange rates off-diagonal, and COVID-19 jointly zero in the equations for conditional variance”. Ultimately, the effectiveness of the outcomes derived from the BEKK-GARCH model was evaluated using Ljung-Box, McLeod-Li, Hosking's multivariate portmanteau Q-statistics, and Multivariate ARCH-Lm tests.

3. RESULTS AND DISCUSSION

In the research, the nominal price series of extra-virgin olive oil and crude olive oil were converted to real terms, and return series were obtained for analysis. The return series' descriptive statistics are shown in Table 1. The results indicate that the return on crude olive oil prices was positive (0.246) and the highest among the series. The higher return on crude olive oil, compared to extra-virgin olive oil during the examined period, may suggest a lower supply of crude olive oil or an increased demand for more affordable alternatives during economic uncertainty, resulting in higher crude olive oil price returns. Additionally, the unconditional variance of the return on the real dollar exchange rate was found to have the lowest volatility (2.265) among the series. The significant variability in the returns of extra-virgin olive oil across the different series is attributable to the consistent increases in the price of extra-virgin olive oil during the analyzed period. The strongest correlation in price levels or closing values was observed between extra-virgin olive oil and crude olive oil, indicating that these two products can be considered substitute goods. This suggests that the volatility spillovers between the relevant markets are transmitted rapidly. The capacity to transfer the effects of current events in one market to rival markets can lead to substantial coordinated movements, exacerbating inflationary pressures during periods of rising or falling prices. This high level of correlation may be attributed to variables like the complementarity or substitutability between the related products (Urak, 2023). The relationship between the return series demonstrates a negative association between extra-virgin olive oil and crude olive oil. Moreover, a negative association was observed between the returns of the two types of olive oils and the exchange rate series. This implies that an increase in dollar exchange rates negatively impacts the returns of these food commodities, due to the increased costs of production resulting from the imported inputs used in the production of extra-virgin and crude olive oils. The leptokurtic distribution of the return series suggests the presence of ARCH effects. This was assessed utilizing the statistical Jarque-Bera test, and the results at the 1% significance level indicated that the series does not adhere to a normal distribution. The ARCH test results rejected the null hypothesis, suggesting the presence of conditionally changing variance for all series, indicating that return volatility changes over time. The ARCH-LM test results indicated that ARCH effects exist in the return series, and the MARCH-LM test demonstrated that the series exhibit

ARCH effects collectively, implying that each series individually possesses ARCH effects and can be analyzed using multivariate GARCH models without issues. The outcomes of the Ljung-Box test showed that the return series exhibit autocorrelation, suggesting that past returns of the series are interrelated and should be considered. The outcomes of an enhanced Dickey-Fuller unit root analysis revealed that the return series are stable at an $I(0)$ level with an importance of 1%, a finding that was further supported by the findings of the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

Table 1: Results of the Unit Root Test and Descriptive Statistics

Statistics	Returns ($R_{j,t}$)		
	$R_{\text{extra-virgin olive (evo)}, t}$	$R_{\text{crude olive oil (coo)}, t}$	$R_{\text{exchange rate (e)}, t}$
Mean	0.202	0.246	-0.151
Std. dev.	16.848	13.978	2.265
Skewnees	-0.077 (0.516)	0.291 ** (0.014)	-1.582 *** (0.000)
Kurtosis	0.450 * (0.058)	1.560 *** (0.000)	15.386 *** (0.000)
Jarque-Berra	4.091 (0.129)	50.077 *** (0.000)	4461.614 *** (0.000)
Correlations between real prices ($Pr_{j,t}$, j = extra-virgin olive (evo), crude olive oil (coo), and dollar exchange rate (e)):			
$Pr_{\text{evo}, t}$		0.983	0.885
$Pr_{\text{coo}, t}$			0.864
Correlations between return series ($R_{j,t}$, j = evo, coo, and e):			
$R_{\text{evo}, t}$		-0.076	-0.024
$R_{\text{coo}, t}$			-0.102
Correlations between squared return series ($R_{j,t}^2$, j = evo, coo, and e):			
$R_{\text{evo}, t}^2$		0.346	0.155
$R_{\text{coo}, t}^2$			0.150
Serial correlations in returns ($R_{j,t}$, j = evo, coo, and e):			
LB-Q (10)	2672.271 (0.000)	3407.340 (0.000)	4218.753 (0.000)
McLeod-Li (10)	2750.045 (0.000)	3444.370 (0.000)	4226.978 (0.000)
HM-Q (10)		7277.645 (0.000)	
ARCH effects in return squared series ($R_{j,t}^2$, j = evo, coo, and e):			
ARCH-LM (10)	153.417 (0.000)	330.427 (0.000)	5824.982 (0.000)
MARCH-LM (10)		276.399 (0.000)	
HM-Q ² (10)		246.048 (0.000)	
Unit Root Tests (Return series ($R_{j,t}$, j = evo, coo, and e)):			
ADF	-25.047 *** (lags=1)	-24.754 *** (lags=1)	-14.321 *** (lags=1)
KPSS	0.009 (lags=1)	0.013 (lags=1)	0.048 (lags=1)

Note: As different lags are used, so do the critical values. An associative p -value is given in parentheses. In that order, 10%, 5%, and 1% of significance, *, **, and *** are statistically significant

Based on the AIC and BIC criteria, it was determined that the optimal number of lags in the VECM system is two. Therefore, the VECM (2) model will be employed in further analyses. Table 2 showcases the mean equation outcomes for the return series derived from the VECM (2)-Asymmetric BEKK-GARCH (1, 1) model. The findings indicate that extra-virgin olive oil is significantly impacted by its own returns with a lag of one and two periods. This pattern in the returns of extra-virgin olive oil is consistent with Ezekiel's (1938) cobweb theory for agricultural commodities. In the extra-virgin olive oil market, increasing returns from one and two periods lag reduce the current returns by $\text{evo}, t-1 = -0.421$ and $\text{evo}, t-2 = -0.235$, respectively. A similar pattern is observed in the crude olive oil market, with returns from one and two periods lag reducing current returns by $\text{coo}, t-1 = -0.663$ and $\text{coo}, t-2 = -0.274$, respectively. This situation implies that rising returns may prompt investors to realize profits and exit the market, thereby reducing present returns. The impact of COVID-19 from one period lag significantly influences returns in the extra-virgin olive oil market, a crucial staple for Türkiye's food industry and extremely vulnerable to the pandemic's impacts. Although COVID-19 has led to an increase in global olive oil prices, it is

predicted that these prices will continue to rise for some time, but at a slower pace (Li, 2024). Thus, the adverse effects of COVID-19 on the olive oil industry are diminishing (Li, 2024). The COVID-19 epidemic has shown to have a positive effect on returns in Türkiye's wheat and sunflower oil markets (Urak et al., 2024). The pandemic has resulted in an increase of over 15% in food commodities prices globally, in numerous African countries, and in India (Hernandez et al., 2020). The study's conclusions are consistent with previous research on how the epidemic has affected commodity prices (Ramsey et al., 2021; Farid et al., 2022; Küçük et al., 2022; Bozma et al., 2023; Urak et al., 2024).

Table 2: The Mean Returns' Parameter Estimates

Parameters	Returns ($R_{j,t}$)	
	$R_{evo,t}$	$R_{coo,t}$
μ	0.099 (0.115)	-0.107 (0.074)
$\Gamma_{evo,t-1}$	-0.421 *** (0.000)	0.023 (0.029)
$\Gamma_{evo,t-2}$	-0.235 *** (0.000)	-0.021 (0.027)
$\Gamma_{coo,t-1}$	0.003 (0.973)	-0.663 *** (0.063)
$\Gamma_{coo,t-2}$	0.002 (0.977)	-0.274 *** (0.052)
ψ_i	0.004 (0.003)	-0.001 (0.002)
ω_i	-0.040 ** (0.020)	0.021 (0.022)
$\Psi_{SQRTH,evo}$	-0.915 (0.117)	0.579 (0.570)
$\Psi_{SQRTH,coo}$	0.354 (0.328)	0.228 (0.191)
ϕ_i	-0.034 *** (0.000)	0.001 (0.004)

Note: Associative standard errors are written in parenthesis. With 10%, 5%, and 1% significance levels, respectively, *, **, and *** are statistically significant.

Table 3 delineates the marginal (unit) effects derived from the VECM (2)-Asymmetric BEKK-GARCH (1, 1) model. The analysis of the return series revealed that the conditional variances are statistically significantly influenced by their own shocks in the brief. This suggests that the extra-virgin and crude olive oil markets in Türkiye are statistically significantly impacted by both negative and positive news. Specifically, the extra-virgin olive oil ($a_{evo,i} = 0.401$) and crude olive oil ($a_{coo,i} = 0.366$) markets exhibit a positive response to their own brief shocks. This can be attributed to the fact that sudden price changes in these markets swiftly alter the behavior and expectations of market participants, resulting in an inclination for prices to increase further. Short-term shocks can create supply-demand imbalances in the market, leading to temporary price increases. Additionally, such shocks can heighten the uncertainty of market participants regarding future price movements, thereby encouraging speculative trading activities, which further amplify price volatility and brief returns. The conditional variance of extra-virgin olive oil returns is directly influenced by its own long-term volatility ($b_{evo,i} = 0.371$). Uncertainties in inter-market bilateral cross interactions have a linear relationship with uncertainties in the crude olive oil market. In this context, volatilities in other markets are transmitted to the crude olive oil market either directly or indirectly, causing uncertainties in this market. For instance, as long-term fluctuations in the extra-virgin olive oil market increases ($b_{evo,i} = -0.183$), uncertainty in the crude olive oil market decreases. When uncertainty rises in the extra-virgin olive oil market, consumers and producers may tend to shift towards crude olive oil, which is generally considered more reliable and stable. This tendency can reduce demand and, consequently, uncertainty in the crude olive oil market. Similarly, fluctuations in the crude olive oil market increase its own market uncertainty ($b_{coo,i} = 0.855$). It has been observed that variations in the dollar exchange rate reduce volatility in the extra-virgin olive oil and crude olive oil markets. Producers might release their

current products to the market and turn to different investment instruments (such as gold, foreign currency, real estate, land, and bank interest yields) because of the Turkish Lira's (₺) decline in value relative to other currencies, particularly the US Dollar (\$). Both Askan et al., (2022) and Urak et al., (2022) emphasize that the fluctuations of food commodities are influenced by the exchange rate in dollars.

Long-term volatilities due to COVID-19 significantly reduce the long-term variance in the extra-virgin olive oil market ($\phi_{1,i} = -0.020$). The reason for this is that COVID-19 lowers long-term uncertainty by increasing returns in the extra-virgin olive oil market. The COVID-19 pandemic has caused fluctuations in the food commodities markets in Türkiye (Küçük et al., 2022; Urak et al., 2024). Countries like Türkiye also attempted to keep local market prices stable throughout the pandemic by restricting the export of food commodities through bans or quotas (Urak et al., 2024). Finally, it has been observed that the effects of both good and negative news on the conditional variances of returns in the extra-virgin olive oil and crude olive oil markets are symmetrical. The volatility caused by COVID-19 has indirectly increased the long-term volatility of extra-virgin olive oil ($\phi_{2,i} = 0.017$). This situation can be attributed to the global pandemic's effects, such as supply chain disruptions, demand changes, and economic uncertainties, which have increased market instability and led to long-term price volatility. The COVID-19 epidemic raised distribution costs, created market uncertainty, sparked demand driven by fear, and significantly increased the volatility of food commodities' short-term prices (Umar et al., 2021; Monge, 2024). The outcomes following COVID-19 are expected to affect olive harvesting, leading to a decrease in worldwide output in the Mediterranean basin. This decrease is primarily due to disruptions in the trade of food commodities, which affected crucial processes such as preparing olive trees for the following harvest. The lack of these processes has led consumers to perceive price increases due to product shortages and rising global demand for olive oil (Francesca et al., 2022). Despite a decrease demanded by eateries and food services, which make up roughly 15% of all olive oil production, total retail sales and olive oil prices have increased in many countries, especially the main producer countries in the EU (Mili & Bouhaddane, 2021).

Table 3: Estimates of Parameters for Conditional Variances

Parameters	Returns	
	$R_{evo, t}$	$R_{coo, t}$
Constants in $\Upsilon\Upsilon'$:		
$c_{evo,i}$	0.116 *** (0.013)	-
$c_{coo,i}$	0.004 (0.008)	0.009 (0.016)
ARCH parameters:		
$a_{evo,i}$	0.401 *** (0.125)	0.062 (0.048)
$a_{coo,i}$	-0.231 (0.180)	0.366 *** (0.115)
GARCH parameters:		
$b_{evo,i}$	0.371 * (0.217)	-0.183 *** (0.064)
$b_{coo,i}$	0.149 (0.114)	0.855 *** (0.035)
GARCH asymmetric parameters:		
$d_{evo,i}$	0.040 (0.178)	0.021 (0.036)
$d_{coo,i}$	-0.370 (0.331)	0.253 (0.226)
Parameters associated with exchange rate (Exr_{t-1}):		
$\psi_{1,i}$	-0.005 *** (0.002)	-

$\psi_{2,i}$	0.001 (0.003)	-0.006 ** (0.003)
Factors related to the price return of several food commodities during the COVID-19 period (COVID-19_{T-1}):		
$\phi_{1,i}$	-0.020 * (0.011)	-
$\phi_{2,i}$	0.017 * (0.010)	0.021 (0.017)
Shape (t degrees)	10.180 *** (3.722)	-

Note: Statistics are significant at 10%, 5%, and 1%, respectively, as indicated by the symbols *, **, and ***.

In Table 4, the results of the hypothesis test for the diagonal GARCH test for VECM (2)-Asymmetric BEKK-GARCH (1, 1) model show Wald = 14.020 ($p < 0.05$). Since the p-value is below the five percentile significance level, H_0 is rejected. The aforementioned test statistics indicate that the mean of the error terms is 0 and their variances are 1. This shows that the model's error terms are statistically standardized and normalized. This finding reveals the existence of indirect and statistically significant interactions between markets, demonstrating the interdependence of food commodities markets and how risks can spread in this context. The Wald hypothesis test outcome for the variance model's off diagonal parameters pertaining to COVID-19 and the dollar exchange rate, indicating they are equal to 0, is found to be 4950.878 ($p < 0.000$). This test statistic shows that the long-term volatilities arising in the COVID-19 and dollar exchange rate markets are transmitted to their own markets by the buyers in other markets. The Wald statistic was used to evaluate the effects of the one and two-period lags of both crude olive oil and the COVID-19 and dollar exchange rate on the returns of extra-virgin olive oil. According to the test results, the hypothesis suggesting that the effects of the one and two-period lags of crude olive oil, the dollar exchange rate, and COVID-19 on extra-virgin olive oil returns are each zero, both individually and simultaneously, has been statistically significantly rejected. This finding indicates that the relevant variables significantly affect the returns in the extra-virgin olive oil market. All these test results confirm that there are robust and statistically significant relationships among the return series mentioned in our previous statements. This demonstrates that modeling extra-virgin olive oil returns based on both its own lags and the lags of other markets is an appropriate approach.

Table 4: A Few Tests for Hypothesis and Diagnostics

Parameters	R _{evo, t}	R _{coo, t}
<i>Panel A: Tests for Residual Diagnostics</i>		
<i>Relatives with Serial Correlation:</i>		
LB-Q(10)	12.496 (0.253)	23.382 *** (0.009)
McLeod-Li(10)	10.235 (0.420)	4.618 (0.915)
HM-Q(10)	89.420 (0.498)	
<i>ARCH Effects in residual squares:</i>		
ARCH-LM(10)	0.504 (0.887)	0.203 (0.996)
HM-Q ² (10)	31.960 (1.000)	
<i>Additional Statistics:</i>		
z	1.1522 (0.249)	-0.059 (0.952)
z ²	425.174 (0.865)	440.841 (0.720)
AIC	-1191.677	
SBC	-1020.512	
HQC	-1124.121	
Log FPE	-1275.677	
Log-Likelihood Value	637.838	
Panel B: Model Specification Tests		
Granger Causality Tests		
H ₀ : Crude olive oil, COVID-19, and dollar exchange rate do not Granger cause extra-virgin olive oil	60.503 (0.000)	
H ₀ : Extra-virgin olive oil, COVID-19, and dollar exchange rate do not Granger cause crude olive oil	10.569 (0.159)	

No GARCH	$H_0: a_{ij} = b_{ij} = d_{ij} = 0$ for all $i, j = 1, 2, 3$	4147.381 (0.000)
Diagonal-GARCH	H_0 : Every off-diagonal element in A, B, and D is zero together	14.020 (0.015)
No-Asymmetry	$H_0: d_{ij} = 0$ for everyone $i, j = 1, 2, 3$	9.431 (0.051)

Notes: Standardized and standardized squared residuals are used by Ljung-Box statistics Q and $Q2$, which assess whether autocorrelation is present in a series. In addition, Hosking's multivariate portmanteau Q -statistics, known as $HM-Q$ and $HM-Q2$, are employed to examine the null hypothesis that autocorrelation does not exist for all series, accounting for a specific number of lags, for both standardized residuals and standardized squared residuals.

CONCLUSION

With the declaration of COVID-19 as a pandemic, various measures were taken globally to limit its effects, leading to significant restrictions on the trade of food commodities. Consequently, this hindered the preparation of olive trees for the next harvest. All these adversities led to a decrease in the supply of olive oil and an increase in olive oil prices due to high consumer demand. The COVID-19 crisis, akin to that of other agri-food industries, revealed the susceptibilities of the olive oil supply chain and emphasized the necessity of fortifying its resistance to worldwide disturbances.

The study's findings show that the conditional variance of extra-virgin and crude olive oil return series is negatively impacted by the one-time delay in closing the dollar exchange rate's value. Uncertainties stemming from the COVID-19 pandemic have been observed to reduce the long-term volatility of extra-virgin olive oil. In the long term, COVID-19 increased uncertainties in inter-market bilateral interactions and seriously threatened food security by adversely affecting consumer access to fundamental food commodities like crude and extra-virgin olive oil. While the conditional variances of crude and extra-virgin olive oil return series are affected by brief shocks, they are observed to change positively in the long term due to uncertainties. This indicates that fluctuations in the olive oil market are shaped by both immediate events and long-term uncertainties. On the other hand, fluctuations in the exchange rate have been observed to reduce the conditional variances of crude and extra-virgin olive oil return series.

Countries facing food security issues need to undertake strategic planning and strengthen supply chain management capacities to ensure food supply, prevent food crises in advance, and maintain uninterrupted supply chain operations during crises like COVID-19. Therefore, it is recommended that policymakers in Türkiye develop policies intended to boost domestic production capabilities of essential food commodities, specifically crude and extra-virgin olive oil. This should be done with consideration of the potential interruption in the food supply chains during global crises. In this context, increasing agricultural supports and incentives for olive producers can contribute to reducing production costs and building a sector resilient to crises. Ultimately, the issue of rising olive oil prices needs to be addressed, and the ability of policymakers and producers to work together is critical in resolving this issue.

Future research could explore several areas to deepen the understanding of the interplay between external shocks and food commodity markets. First, including additional agricultural products could provide broader insights into the resilience of food supply chains under global crises. Second, integrating regional and international trade dynamics could elucidate the cross-border implications of market volatilities in globalized supply chains. Third, examining alternative stabilization policies, such as strategic reserves or subsidies, could offer practical solutions for mitigating volatility in key markets. Finally, leveraging advanced machine learning techniques could enhance the predictive accuracy of market dynamics,

offering valuable tools for policymakers.

ETİK BEYAN VE AÇIKLAMALAR

Etik Kurul Onay Bilgileri Beyanı

Çalışma, etik kurul izni gerektirmeyen bir çalışmadır.

Yazar Katkı Oranı Beyanı

Yazarlar tüm çalışmaları birlikte yürütmüştür.

Çıkar Çatışması Beyanı

Çalışmada potansiyel bir çıkar çatışması bulunmamaktadır.

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